Rubber hand illusion, empathy, and schizotypal experiences in terms of self-other representations

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Abstract

When participants observed a rubber hand being touched, their sense of touch was activated (rubber hand illusion: RHI). While this illusion might be caused by multi-modal integration, it may also be related to empathic function, which enables us to simulate the observed information. We examined individual differences in the RHI, including empathic and schizotypal personality traits, as previous research had suggested that schizophrenic patients would be more subject to the RHI. The results indicated that people who experience a stronger RHI might have stronger empathic and schizotypal personalities simultaneously. We discussed these relationships in terms of self-other representations.

1. Introduction

Watching a rubber hand being stroked synchronously with one's own unseen hand for a short time causes the observer to attribute the rubber hand to one's own body, to "feel like it's my hand" (rubber hand illusion: RHI). The observation activated their own sense of touch (Botvinick & Cohen, 1998; Tsakiris & Haggard, 2005). Previous studies have suggested that both bottom-up and top-down processing might be involved in producing the RHI (Costantini & Haggard, 2007). The former involves the incorporation of the rubber hand into the experience of one's own body and depends on the visual stimulation of the rubber hand matching the tactile stimulation of the actual hand. Previous studies have shown that the RHI is sensitive to the temporal pattern of stimulation (Tsakiris & Haggard, 2005) and the spatial aspects of matching (Costantini & Haggard, 2007), indicating that the RHI may need multi-modal integrations.

The latter level involves body posture (Austen, Soto-Faraco, Enns, & Kingstone, 2004; Ehrsson, Spence, & Passingham, 2004), visual appearance (Tsakiris & Haggard, 2005), and hand identity (Tsakiris, Prabhhu, & Haggard, 2006). These studies showed that large incongruities between the rubber hand and the participant's hand, which might affect the participants' top-down cognition regarding whether the rubber hand could replace their own hand, reduced the illusion, indicating that the RHI may also be related to the mapping between the rubber hand and the real hand or the empathic function, which could enable us to generate anticipation of the same experience in ourselves (e.g., simulation theory; Jeannerod & Pacherie, 2004). Indeed, some recent studies have suggested that the empathic function might drive the RHI (Durgin, Evans, Dunphy, Klostermann, & Simmons, 2007; Schutz-Bosbach & Prinz, 2007), but there is no direct evidence between empathy and the RHI. In the present study, we examined this relationship by focusing on individual differences in the RHI.

Schizophrenic patients may experience a stronger RHI than healthy controls (Peled, Ritsner, Hirschmann, Geva, & Modai, 2000). Therefore, we also focused on the schizotypal personality in the general population. Patients with schizophrenia are...
impaired in perceptual as well as cognitive functions. In the past dozen years, several theoretical models of schizophrenia symptoms have been proposed, often inspired by advances in cognitive neuroscience. It was recently suggested that these models of schizophrenia may also apply to schizotypal personality traits (e.g., Asai, Sugimori, & Tanno, 2008; Asai & Tanno, 2007, 2008). Cyhlarova and Claridge (2005) indicated that people with schizotypal traits, identified by questionnaires or semi-structured interviews, might have a predisposition to schizophrenia. Although schizotypal people can have schizophrenic-like experiences, many can live normal lives (Cyhlarova & Claridge, 2005). We hypothesized that people who experience a stronger RHI might have the schizotypal and empathic personalities simultaneously. We also examined the directional relationship among these personality traits and the RHI.

2. Method

2.1. Participants

Seventy-two university students (36 men and 36 women, mean age = 19.7 years, range = 18–24 years, 3 people are left-handed [H. N. Handedness scale; Hatta & Kawakami, 1995]) participated in the study. These participants (not all psychology majors) were recruited randomly from an introductory psychology class participant pool. All participants were naive with respect to the purpose of the study. We obtained written informed consent from all participants before conducting the experiment. All participants reported normal or corrected-to-normal vision, hearing, and somatosensory, and no neurological abnormalities.

2.2. Apparatus and procedures

We followed the standard RHI procedure (e.g., Botvinick & Cohen, 1998; Peled et al., 2000). Participants sat at a table across from the experimenter with their arms resting on the table. A standing screen was positioned beside the arm to hide it from the participant’s view, and a life-sized rubber model of a hand and arm was placed on the table directly in front of the subject. The participant sat with eyes fixed on the artificial hand while two small paintbrushes were used to synchronously stroke the rubber hand and the participant’s hidden hand. The stroking was manually delivered by the experimenter. The distance between the participant’s hand and the rubber hand was about 20 cm.

The experiment consisted of two blocks, right and left hand blocks. The order was counterbalanced across the participants. A pre-test proprioceptive location judgment was obtained by asking the participants, with their eyes open, to indicate where it felt like the tip of their middle finger was located by reporting the corresponding number along a ruler, which was laid across the table, parallel to their frontal plane. We instructed participants to report the location of their middle finger as accurately as possible because the task is intended to measure participants’ body sense. Participants were not informed that this task could also be used to measure illusional location. A random ruler offset that varied from trial to trial (and from pre to post-test) was used to discourage the participants from re-using verbal labels from previous trials, and to prevent participants from using a particular strategy or from being influenced by demand characteristics (e.g., Schutz-Bosbach, Tausche, & Weiss, 2009).

Following the pre-test judgment, a 120-s induction phase began in which both the rubber hand and the participant’s hand were brushed with two identical paintbrushes. Brush strokes were made at approximately 1 Hz. After the induction, a post-test proprioceptive location judgment was made in the same manner as the pre-test. Following this proprioceptive judgment, the RHI questionnaire (Botvinick & Cohen, 1998; Peled et al., 2000) was administered. Participants were asked to indicate the extent of their agreement or disagreement with nine statements (e.g., “It seemed as if I were feeling the touch of the paintbrush in the location where I saw the rubber hand touched”) in each block, using a 7-item Likert scale (ranging from –3 to +3) (see Table 1 for each item).

Three experimental indices were obtained from this procedure. RHI questionnaire scores were averaged to obtain a mean RHI score for each participant (we refer to the results of each questionnaire item later, when necessary), which provides the subjective measure of the RHI (Botvinick & Cohen, 1998). Pre-test proprioceptive location errors consisted of the absolute distance between the participants’ reports and the actual locations before the induction phase. This provided the control measure for individual differences since this measure is not related to RHI. Proprioceptive drifts were the distances between the participants’ pre- and post-test reports of locations, which provide the objective measure of the RHI (Botvinick & Cohen, 1998). We expected that the two RHI measures (questionnaire and drift) would be related to the schizotypal and empathic personality traits and that pre-test proprioceptive location error would not be related to them.

2.3. Personality questionnaires

After the participants finished the experiment, they completed a battery of questionnaires. Higher scores reflect stronger personality traits.

1. Empathic personality traits: the Interpersonal Reactivity Index (IRI; Davis, 1980) is a well-known 28-item instrument containing four 7-item subscales assessing different dimensions of empathy: Perspective Taking, Empathic Concern, Personal Distress, and Fantasy (Davis, 1980, 1983). Each item is scored on a 5-point Likert scale, ranging from 0 (does not
While pre-test location error was not correlated with any of the personality traits (Table 2), the results indicated that RHI sensitivity was significantly correlated with Positive Schizotypy in SPQB (Table 2). Then, by averaging RHI questionnaire and proprioceptive drifts after both measures were standardized, we finally calculated the index for RHI sensitivity. Higher RHI sensitivity scores indicated that the participant would be more subject to the RHI.

Table 2 shows the correlation matrix between each RHI questionnaire item and proprioceptive drift (see Supplementary Table S1 for mean responses for each item), indicating that most combinations among the questionnaire items were significant and that most items significantly correlated to proprioceptive drift (cf., Longo et al., 2008, for comparison of items that predict proprioceptive drift). Therefore, to simplify, we decided to use the averaged RHI questionnaire scores across nine items for further analysis. As expected, the averaged RHI questionnaire scores and the proprioceptive drifts values were highly correlated with each other ($r = .47$, $p < .01$), while the pre-test location errors and questionnaire scores, and pre-test location errors and proprioceptive drifts were not significantly correlated with each other ($p > .20$), indicating that both RHI questionnaire and proprioceptive drifts might be the indices for the RHI, and that pre-test location errors might not affect RHI (Table 2). Then, by averaging RHI questionnaire and proprioceptive drifts after both measures were standardized, we finally calculated the index for RHI sensitivity. Higher RHI sensitivity scores indicated that the participant would be more subject to the RHI.

To examine the relationship between the RHI and potential personality traits, we conducted a correlation analysis (see Table 2 and Supplementary Table S2 for the correlation between each RHI questionnaire item and personality traits). The results indicated that RHI sensitivity was significantly correlated with Positive Schizotypy in SPQB ($r = .37$, $p < .01$), with IRI (empathy traits) total ($r = .27$, $p < .05$), and with Empathic Concern in IRI ($r = .31$, $p < .01$) (see Fig. 1 for the scatter plots), while pre-test location error was not correlated with any of the personality traits (Table 2).

The results suggested that there was a relationship between the RHI and Positive Schizotypy, and between the RHI and empathic traits, especially Empathic Concern. The correlation between the Positive Schizotypy and Empathic Concern, however, was not significant ($r = .14$, $p > .20$). Although previous studies that examined the relationship between schizotypy or schizophrenia and empathy by using questionnaires have not reported consistent results (Dinn, Harris, Aycicegi, Greene, & Andover, 2002; Henry, Bailey, & Rendell, 2008; Montag, Heinz, Kunz, & Gallinat, 2007), our null result was also found in a separate questionnaire survey employing a larger sample ($N = 283$, $r = .08$, $p > .15$). Based on our analyses, we constructed the following path models: Empathic Concern $→$ RHI sensitivity $→$ Positive Schizotypy (or Empathic Concern $→$ RHI sensitivity $→$ Positive Schizotypy, same model statistically) and Empathic Concern $→$ RHI sensitivity $→$ Positive Schizotypy. We compared the two path models’ fitness indices using AMOS 16.0 J. Both models had good fitness values, but the comparison

**Table 1**

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<th>Item</th>
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<td>Proprioceptive drift</td>
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<td>.47</td>
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<td>.38</td>
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<td>.40</td>
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<td>1. “It seemed as if I were feeling the touch of the paintbrush in the location where I saw the rubber hand touched”</td>
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<td>.49</td>
<td>.47</td>
<td>.26</td>
<td>-.01</td>
<td>.07</td>
<td>.17</td>
<td>.14</td>
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<td>2. “It seemed as though the touch I felt was caused by the paintbrush touching the rubber hand”</td>
<td>-</td>
<td>.45</td>
<td>.16</td>
<td>.26</td>
<td>.05</td>
<td>.41</td>
<td>.19</td>
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<td>3. “I felt as if the rubber hand was my hand”</td>
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<td>.58</td>
<td>.33</td>
<td>.24</td>
<td>.51</td>
<td>.32</td>
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<td>4. “I felt as if my (real) hand were drifting toward the right (toward the rubber hand)”</td>
<td>-</td>
<td>.52</td>
<td>.51</td>
<td>.69</td>
<td>.59</td>
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<td>5. “It seemed as if I had more than one left (or right) hand”</td>
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<td>.44</td>
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<td>.48</td>
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<td>6. “It seemed as if the touch I was feeling came from somewhere between my own hand and the rubber hand”</td>
<td>-</td>
<td>.50</td>
<td>.64</td>
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<td>.42</td>
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<td>7. “It felt as if my (real) hand was turning “rubbery”</td>
<td>-</td>
<td>.52</td>
<td>.38</td>
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<td>.38</td>
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<td>8. “It appeared (visually) as if the rubber hand where drifting toward the left (towards my hand)”</td>
<td>-</td>
<td>.61</td>
<td>.61</td>
<td>.61</td>
<td>.61</td>
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<tr>
<td>9. “The rubber hand began to resemble my own (real) hand, in terms of shape, skin tone, freckles or some other visual feature”</td>
<td>-</td>
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Note: $N = 72$.

* $p < .10$.

** $p < .05$.

*** $p < .01$.

**describe me well** to 4 (**describes me very well**), Perspective Taking and Fantasy might be cognitive empathic traits while Empathic Concern and Personal Distress might be emotional empathic traits (Davis, 1983).

2. Schizotypal personality traits: the Schizotypal Personality Questionnaire Brief (SPQB; Raine & Benishay, 1995) is a shortened version of the Schizotypal Personality Questionnaire (SPQ; Raine, 1991). SPQB is a 22-item true–false self-report questionnaire measuring schizotypal personality traits. It consists of three subscales: Cognitive-Perceptual (Positive Schizotypy), Interpersonal (Negative Schizotypy), and Disorganization (Disorganized Schizotypy).

3. Results

There were no gender differences in the experimental and personality indices, and there were no laterality effects (that is, the difference between the right and left conditions) in the experimental indices (e.g., Ocklenburg, Ruther, Peterburs, Pinnow, & Gunturkun, 2010). Consequently, the scores of the right and left conditions were averaged for the experimental indices, and the data for male and female participants were combined for all subsequent analyses.

Table 1 shows the correlation matrix between each RHI questionnaire item and proprioceptive drift (see Supplementary Table S1 for mean responses for each item), indicating that most combinations among the questionnaire items were significant and that most items significantly correlated to proprioceptive drift (cf., Longo et al., 2008, for comparison of items that predict proprioceptive drift). Therefore, to simplify, we decided to use the averaged RHI questionnaire scores across nine items for further analysis. As expected, the averaged RHI questionnaire scores and the proprioceptive drifts values were highly correlated with each other ($r = .47$, $p < .01$), while the pre-test location errors and questionnaire scores, and pre-test location errors and proprioceptive drifts were not significantly correlated with each other ($p > .20$), indicating that both RHI questionnaire and proprioceptive drifts might be the indices for the RHI, and that pre-test location errors might not affect RHI (Table 2). Then, by averaging RHI questionnaire and proprioceptive drifts after both measures were standardized, we finally calculated the index for RHI sensitivity. Higher RHI sensitivity scores indicated that the participant would be more subject to the RHI.

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Table 2

Intercorrelations of personality and experimental indices.

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<td><strong>Personality indices</strong></td>
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<tr>
<td>1. SPQB total</td>
<td>.82**</td>
<td>.85**</td>
<td>.82**</td>
<td>.29</td>
<td>-.01</td>
<td>.25</td>
<td>.09</td>
<td>.25</td>
<td>.13</td>
<td>.23</td>
<td>.16</td>
<td>.23</td>
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<tr>
<td>2. Positive schizotypy</td>
<td>.51**</td>
<td>.50**</td>
<td>.33</td>
<td>.07</td>
<td>.28</td>
<td>.14</td>
<td>.20</td>
<td>.08</td>
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<td>3. Negative schizotypy</td>
<td>.59</td>
<td>-.14</td>
<td>-.03</td>
<td>.18</td>
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<td>4. Disorganized schizotypy</td>
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<td>-.26</td>
<td>-.07</td>
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<td>-.01</td>
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<td>5. IRI total</td>
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<td>6. Perspective taking</td>
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<td>.43**</td>
<td>.69**</td>
<td>.56**</td>
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<td>7. Fantasy</td>
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<td>-.16</td>
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<td>8. Empathic concern</td>
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<td>.21</td>
<td>.04</td>
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<td>9. Personal distress</td>
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<td>.22</td>
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<td>10. Pre-test location error</td>
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<td>.15</td>
<td>.13</td>
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<td>11. Questionnaire score</td>
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<td>.47**</td>
<td>.86</td>
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<td>12. Proprioceptive drift</td>
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Note: N = 72. SPQB = Schizotypal Personality Questionnaire Brief. IRI = Interpersonal Reactivity Index. Perspective Taking and Fantasy might be the cognitive empathic traits while Empathic Concern and Personal Distress might be the emotional empathic traits (Davis, 1983). RHI sensitivity = Ruber Hand Illusion sensitivity (Questionnaire Score + Proprioceptive Drift).

* p < .10.
** p < .05.
*** p < .01.

Fig. 1. Scatter plots between the RHI sensitivity and each questionnaire scores. Note: N = 72. RHI sensitivity = Ruber Hand Illusion sensitivity (RHI questionnaire + proprioceptive dirift). IRI = Interpersonal Reactivity Index.

Fig. 2. Potential path models among RHI sensitivity, Empathic Concern, and Positive Schizotypy. Note: In path analysis, the constructed models can be evaluated using multiple measures: the χ² test, GFI (Goodness of Fit Index), AGFI (Adjusted GFI), NFI (Normer Fit Index), CFI (Comparative Fit Index), RMSEA (Root Mean Square Error of Approximation), and AIC (Akaike Information Criterion). If the χ² value resulting from the χ² test is greater than 0.05, the model is thought to have good fit. If the values of GFI, AGFI, NFI, CFI are greater than 0.90 (or 0.95 in a more stringent analysis), the model is thought to have good fit (e.g., Bentler and Bonnet, 1980; Hu & Bentler, 1999). If the value of RMSEA is less than 0.10 (or 0.05 in a more stringent analysis), the model is thought to have good fit (e.g., Browne and Cudeck, 1993). Generally speaking, when the model has more than two good scores, including RMSEA and one other, the model is considered to have good fit. AIC is a comparative measure to compare two models with good fit; a smaller value indicates good fit.
between the two models revealed that the former model was superior in fit (see AIC scores in Fig. 2). Statistically speaking, empathic personality traits might drive the sensitivity of RHI, and this might lead to positive symptomatology of schizotypal traits. Although the path analysis does not provide information about directional causality since it depends on an a priori hypothesis, this model suggests a possible relationship between empathy, schizotypy, and RHI in terms of self-other representation, as we discuss below.

4. Discussion

The present study examined individual differences in the rubber hand illusion in which participants’ sense of touch is activated after observing a rubber hand being touched. It has been assumed that multi-sensory interaction could cause RHI. However, some recent studies shed light on new aspects of RHI. RHI might also be caused by simple observation of a rubber hand being touched by a laser light, a situation in which there is no multi-sensory induction (Durgin et al., 2007). Rather, it seems that an empathic function could enable us to generate anticipation of the same experience in ourselves (e.g., Keysers et al., 2004). Other studies reported that body posture, visual appearance, and hand identity (e.g., Tsakiris et al., 2006) might affect RHI, indicating that RHI might also need the sense of body ownership. Multi-modal interaction alone could not explain RHI. Rather, the possibility of identifying the rubber hand with one’s own body empathically might be important. People with schizophrenia might have deficits in multi-modal integration, and as a result they might have weaker multi-modal illusion (e.g., de Gelder, Vroomen, Annen, Masthof, & Hodiamont, 2003). However, Peled et al. (2000) showed that people with schizophrenia might have stronger RHI, although they had predicted the opposite result based upon previous studies, indicating that those with schizophrenia might have deficits in self-other representation or empathy in terms of RHI.

Since RHI requires spatial and temporal matching (Costantini & Haggard, 2007; Tsakiris & Haggard, 2005), this illusion does not impact most people in their daily lives. For some people, however, a similar phenomenon called mirror-touch synesthesia (Blakemore, Bristow, Bird, Frith, & Ward, 2005) impacts their daily lives, in that the observation of touch on other humans results in tactile sensations on their own body. Recent studies have suggested that mirror-touch synesthesia might be linked with more empathic personality traits (“emotional reactivity”), and some people with mirror-touch synesthesia might respond even to non-human objects (Banissy, Cohen Kadosh, Maus, Walsh, & Ward, 2009; Banissy & Ward, 2007). If RHI might be caused even by simple observation of a rubber hand being touched (Durgin et al., 2007), RHI, empathic self-other mapping (feeling the sensation of the other being touched, Keysers et al., 2004), and mirror-touch synesthesia might be associated with empathic personality traits. Multi-modal induction for RHI might be the “induction” for empathic mapping between self and others.

We first demonstrated that there is a relationship between the RHI and empathic personality. This is consistent with previous research, which suggests that the RHI might be related to empathy (Durgin et al., 2007). Of the empathic personality subcategories, it appears that Empathic Concern might be strongly related to the RHI. Empathic Concern might be one of the emotional empathic functions, and is defined as “other-oriented feelings of warmth, compassion and concern for others” or, in other words, a motivation to approach others (Davis, 1980, 1983). In the case of the present study, people who would be concerned more about the rubber hand or the rubber hand being touched might experience a stronger RHI. Cognitive components of empathy might be related to adopting the perspective of others, or developing a theory of mind by imagining the cognitive state of another based on visual, auditory, or situational cues, while emotional components of empathy include the ability to recognize other people’s emotions (Rankin et al., 2006). In that sense, since RHI seems not to include emotional responses (see RHI questionnaire items, for example) and it might be a visually driven illusion, we might intuitively think that the RHI could be more related to cognitive empathy than emotional empathy. However, given the fact that mirror-touch synesthesia might also be related to emotional empathy (not cognitive empathy) (Banissy & Ward, 2007), and Empathic Concern has been previously shown to correlate with higher neural sharing of observed pain (Singer et al., 2004), this may mean that experiencing aspects of emotional (not cognitive) empathy may, particularly, depend on shared interpersonal (and with a non-human object) representations (Banissy & Ward, 2007; Lawrence et al., 2006).

In addition, previous research has suggested that schizophrenic patients might experience a stronger RHI. For instance, it was found that the hallucination in positive symptomatology was related to the RHI (Peled et al., 2000). However, Peled et al. only used an RHI questionnaire, and therefore demand characteristics may not have been controlled. In line with previous research, our results suggested that there is a relationship between the positive schizotypal personality and the RHI. Previous research suggested that positive symptomatology, including hallucinations both in schizophrenic patients and individuals with non-clinical schizotypal personalities, might be caused by the self-other misattribution in self-action (Asai & Tanno, 2007) or self-body (including self-face, Platek & Gallup, 2002) recognition (Arzy, Mohr, Michel, & Blanke, 2007). That is, they could not attribute their own action or body to themselves but, rather, to others. Contrary to this, the relationship between the RHI and schizophrenic positive experiences might be in the opposite direction: individuals could excessively attribute others’ feelings to themselves. In sum, schizotypal people might have abnormalities in self-other representations, including both empathy (connection between self and others) and agency (discrimination of self from others).

These two superficially-opposite processes might be generated by a shared neural mechanism, that is, the mirror-neuron system (Miall, 2003; Pineda, 2008). Brain imaging studies have suggested that the two processes have common brain activity...
areas (i.e., a “shared circuit”), indicating a potential and essential control mechanism of these processes. Indeed, some studies have suggested that deficits in the mirror-neuron system are associated with people with schizophrenia (Buccino & Amore, 2008). We speculate that our statistical model, although it does not provide information about directional causality, could be interpreted to mean that empathic personality traits increase susceptibility to the RHI, which in turn can lead to schizotypal experiences, including an abnormal sense of self. First, although empathetic functioning is needed to thrive socially, there are limits, and an excessively empathic personality might lead to deficits in self-other representation, as seen in mirror-touch synesthesia (Blakemore et al., 2005). It has also been suggested that the skin temperature of participants’ arms gets lower during RHI induction, which could be interpreted to suggest that RHI causes participants to lose the sense of their own arm (Moseley et al., 2008). Higher bodily empathy for others might also cause individuals to lose the sense of their own body in terms of RHI, given that RHI and other whole body illusions (Lenggenhager, Tadi, Metzinger, & Blanke, 2007) demonstrate the plasticity of our body representation. Second, people who can lose their own bodily sense easier (and therefore who might have higher RHI sensitivity) might be more likely to replace their own lost sense of ownership and agency with the sense of body or action of an outside agent. Such passivity phenomena, where an individual has a sense that their actions, thoughts, or emotions are created for them by some external agent, are part of the positive symptoms of schizophrenia. In most cases, the actions carried out by people who feel that they are being controlled by alien forces are not discrepant with their own intentions (Frith, Blakemore, & Wolpert, 2000). As noted previously, it has been suggested empirically that schizophrenic patients or people with higher schizotypy cannot attribute their own action or body to themselves, but instead attribute their actions to others (Arzy et al., 2007; Asai & Tanno, 2007; Platek & Gallup, 2002), indicating a weakened sense of self. Although the present finding that people who are more susceptible to RHI have schizotypal and empathic personality could be interpreted to mean that empathic personality traits increase susceptibility to the RHI, which in turn can lead to a comprehensive understanding of how the mirror-neuron system mediates empathy, agency, and mental disorders.

Appendix A. Supplementary material

Supplementary data associated with this article can be found, in the online version, at doi:10.1016/j.concog.2011.02.005.

References


